Impact of Convection and Domain Size on Precipitation Forecasts for the U.S. West Coast in the Atmospheric River Analysis and Forecast System (AR-AFS)

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1. Introduction

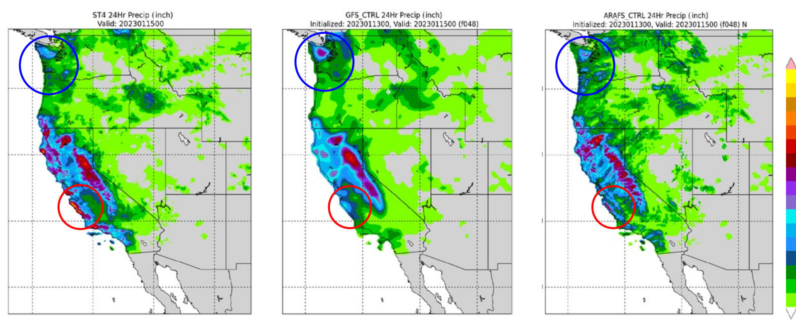
Atmospheric rivers (ARs) are critical components of the global water cycle, significantly influencing both flood hazards and water supply, especially in western North America. The Atmospheric River Analysis and Forecast System (AR-AFS), a high-resolution regional model, was developed to provide numerical guidance for AR forecasts. This paper reports our ongoing work in optimizing the model's physics and domain configuration to elevate the AR-AFS to a higher NOAA Readiness level. Specifically, we investigate the impact of convection and domain size on precipitation forecasts on the U.S. West Coast.

2. AR-AFS Model

The AR-AFS model is built on the Unified Forecast System (UFS), which employs the Finite-Volume Cubed-Sphere (FV3) Dynamical Core. It offers a high horizontal resolution of approximately 3 km over the Northeast Pacific and Western North America, utilizing initial and boundary conditions from the GFSv16 to provide 5-day forecasts. Table 1 shows physics parameterizations used in AR-FS, including Thompson Microphysics, GFDL PBL, the Scale-Aware Mass-Flux (SAMF) convection scheme etc. Figure 1 illustrates AR-AFS's ability to accurately capture the fine structures of the observed precipitation on watersheds.

Table. 1 AR-AFS model physics

Microphysics	Thompson
PBL	EDMF-TKE
Surface layer	GFDL
Land surface	Noah
Radiation	RRTMG
Convection	SAMF



Stage-IV GFSv16 AR-AFS

Fig. 1 The 24-48h total precipitation ending at 00 UTC 15 January 2023 from Stage-IV (ST4), GFSv16, and AR-AFS. Blue circle: a structure with precipitation over-estimated by GFSv16. Red circle: a coastal watershed "Salinas" with heavy precipitation.

3. Experiments

The AR-AFS model uses the Extended Schmidt Gnomonic (ESG) grid where a Schmidt stretching factor S scales the domain by $1/S$ (Purser et al. 2020). The near-real-time AR-AFS experiment uses S=1.0 and the Scale-Aware Mass-Flux (SAMF) convection scheme. In this study, we evaluate four experiment settings (Table 2) of AR-AFS, (1) with convection scheme enabled and S=1.0; (2) with convection scheme turned off and S=1.0; (3) with convection scheme enabled and S=0.8; and (4) with convection scheme turned off and S=0.8. These settings utilize 30 forecast cycles spanning the AR days from November 2022 to March 2023.

Table. 2 The experiment configuration with AR-AFS

Experiments	**AR-AFS-1.0**	**AR-AFS-1.0-No-Conv**	**AR-AFS-0.8**	**AR-AFS-0.8-No-Conv**
Stretching Factor *S*	1.0	1.0	0.8	0.8
Convection	ON	OFF	ON	OFF

The hypotheses are: (1) AR-AFS precipitation forecast is not sensitive to the convection scheme since the AR introduced rainfall is mostly non-convective; (2) increasing domain size impacts forecast accuracy because the coverage of synoptic phenomena and the resolution of the underlining ESG grid are changed accordingly.

The precipitation forecasts are evaluated against ST4 observations using standard metrics such as Mean Absolute Error (MAE) and Hit Rate for the U.S. West Coast. Sample forecasts and their differences in this study are shown in Figures 2 and 3, while the performance of AR-AFS with the four settings is shown in Figure 4. The verification domain used is the U.S. West Coast domain (WEST) from Lord et al. 2023. The findings indicate that (1) the use of convection schemes makes no significant difference and, (2) no significant impact is found for domain size, although reducing the stretch factor decreases skill slightly.

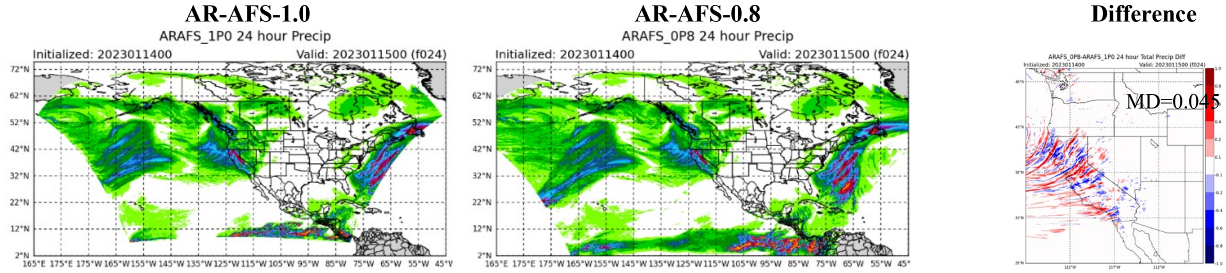


Fig. 2 0-24h total precipitation forecasts in WEST, initialized on January 14, 2023, from AR-AFS with two domain sizes (*S*=1.0 and *S*=0.8) and their difference with the mean absolute difference (MD) of 0.045 inch.

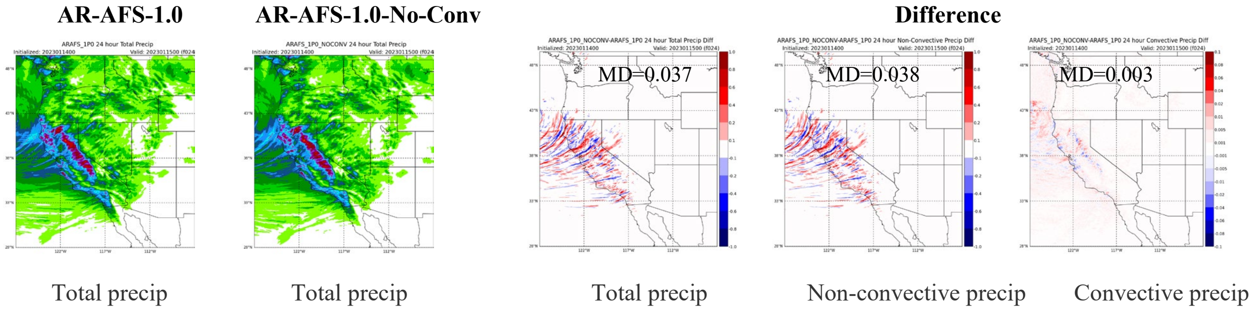


Fig. 3 AR-AFS 0-24h precipitation forecasts in WEST, initialized on January 14, 2023. Left: total precipitation with and without convection scheme. Right: two forecasts' difference in total precipitation, non-convective precipitation, and convective precipitation.

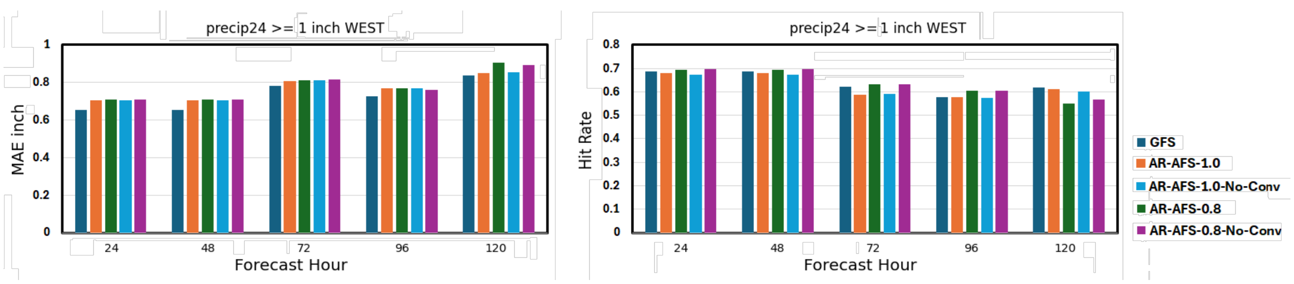


Fig. 4 AR-AFS's performance on the region averages of MAE (left) and average Hit rates (right) of 24-hour precipitation forecast with a 1.0 inch ST4 precipitation cutoff in WEST.

4. Summary

Our previous study highlighted the sensitivity of AR-FS precipitation forecasts in the U.S. West to microphysical and PBL Schemes (Wu et al. 2024). This study indicates that convection schemes and slightly enlarged domain size have minimal or negligible impacts on AR-AFS precipitation forecasts. The findings from these studies will be used to guide the optimization of the AR-AFS configuration for the next AR season. Additional experiments will be conducted to explore AR-AFS physics and configurations, including (1) an extended domain covering the U.S. East Coast and Guam, and (2) a new combination of physics with the convection scheme turned off.

References

Purser, R.J, D. Jovic, G. Ketefian, T. Black, J. Beck, J. Dong, and J. Carley, The extended Schmidt Gnomonic grid for regional applications. 1st UFS Users' Workshop, July 27-29, 2020.

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